National Aeronautics and
Space Administration

ESTF 2020

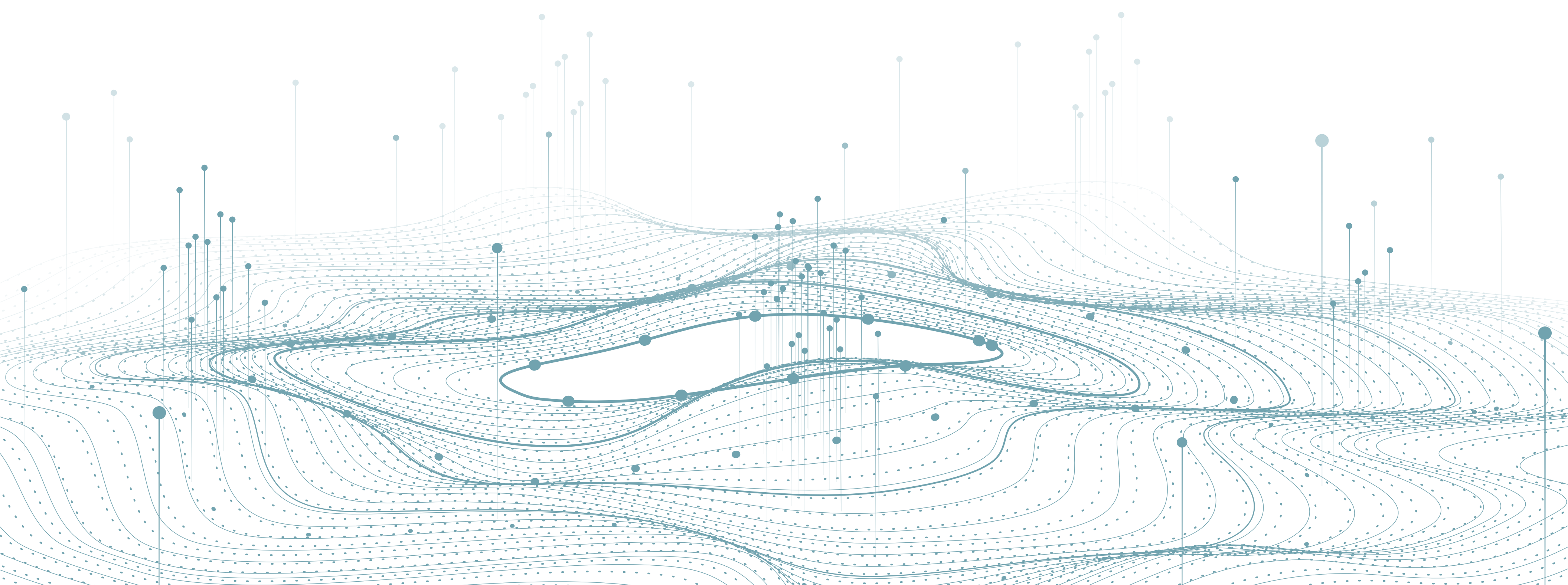
EARTH SCIENCE TECHNOLOGY FORUM

JUNE 23-25, 2020

WELCOME

Welcome to the 2020 Earth Science Technology Forum. We are delighted to have presenters and attendees gather virtually on 23, 24 and 25 June.

The forum is an annual event hosted by NASA's Earth Science Technology Office (ESTO) to share cutting edge technologies that aim to improve Earth observations.



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(All times are in Eastern Daylight Time)

PLENARY

Pamela S. Millar
Karen St. Germain

June 23 // 1:00PM

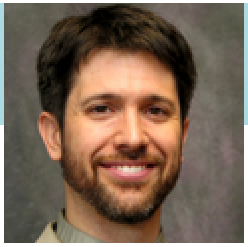
Pam Millar, director of NASA's Earth Science Technology Office, will welcome everyone to our first virtual Earth Science Technology Forum and introduce Karen St. Germain, the new Director of NASA's Earth Science Division. Just prior to joining NASA, Karen was the Deputy Assistant Administrator, Systems for NOAA's Satellite and Information Service.

CUBESATS

CubeSats, or shoebox-sized satellites, are an ideal platform to test novel Earth science technologies. Investigators have looked to CubeSats and SmallSats to validate microwave technologies, polarimeters and even a radar. These researchers are in various stages of development; while some are preparing their instruments for launch, others are collecting valuable science information from instruments already in orbit.

23 Jun 2020 // 1:40PM - 2:50PM

TEMPEST-D: Temporal Experiment for Storms and Tropical Systems Demonstration // EVI-2



Steven C. Reising
Colorado State University
steven.reising@colostate.edu

Technology: TEMPEST-D demonstrates the on-orbit capabilities of a new five-frequency millimeter-wave radiometer to enable a closely-spaced constellation of 6U CubeSats to sample rapid changes in convection and water vapor every five minutes.

Science: Spaceborne passive microwave temperature and water vapor sounding of the Earth's atmosphere provides the most valuable quantitative contribution to weather prediction and is indispensable to improve climate models.

Highlights: Recent advances in CubeSats have motivated NOAA and EUMETSAT to explore the value of launching passive microwave sounders on small, low-cost spacecraft, providing the potential for deployment of low-Earth orbit constellations to substantially shorten revisit times. In this context, TEMPEST-D is the first CubeSat-based multi-frequency microwave sounder to provide global data over a substantial period. The team will discuss its well-calibrated passive microwave atmospheric sounder CubeSat after nearly two years on orbit. TEMPEST-D brightness temperatures have been validated through comparison with those of GPM/GMI and MHS operational satellites, demonstrating high accuracy and precision. In addition, TEMPEST-D data have been used to demonstrate data assimilation into NOAA numerical weather prediction models and atmospheric science parameter retrievals. On-orbit results demonstrate that TEMPEST-D is a very well-calibrated, highly stable radiometer, indistinguishable in performance from larger, more expensive operational sensors.

Co-Authors: Todd C. Gaier(2), Shannon T. Brown(2), Sharmila Padmanabhan(2), Christian D. Kummerow(3), Wesley Berg(3), V. Chandrasekar(1), Boon H. Lim(2), Cate Heneghan(2), Richard Schulte(3), Yuriy Goncharenko(1), C. Radhakrishnan(1), Matthew Pallas(4), Doug Laczkowski(4), Nancy Gaytan(4) and Austin Bullard(4) 1. Electrical and Computer Engineering Dept., Colorado State University, Fort Collins, CO USA 2. NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA USA 3. Atmospheric Science Dept., Colorado State University, Fort Collins, CO USA 4. Blue Canyon Technologies, Boulder, CO USA

RainCube: Radar In a CubeSat // InVEST-15

Shivani Joshi
Jet Propulsion Laboratory
shivani.s.joshi@jpl.nasa.gov

Technology: RainCube is the first radar mission and active payload in a 6U CubeSat.

Science: Numerical climate and weather models depend on measurements from space-borne satellites to complete model validation and improvements. RainCube could enable constellation missions that revolutionize climate science and weather forecasting.

Highlights: In the fall of 2018, within the first two months of mission operations, RainCube achieved mission success by demonstrating its novel miniaturized radar architecture and deployable Ka-band mesh antenna in space. The mission has since been extended six times and is currently in its final extended mission phase. During its extended mission phases, RainCube has demonstrated platform capabilities and validated science objectives that will be invaluable for future studies and mission proposals. The team will review the mission from concept through mission success and continued operations. It will present key science results, including those of on-orbit experiments, and lessons learned from two years of operations. The team will also give a brief summary of upcoming opportunities that are enabled by RainCube's success.

PI: Eva Peral **Co-Authors:** S. Joshi, E. Peral, S. Tanelli, S. Statham, O. Sy, R. Beauchamp, C. Shaffer

CIRiS: Compact Infrared Radiometer in Space // InVEST-15

David Peter Osterman
Ball Aerospace
dosterma@ball.com

Technology: CIRiS is a multispectral, LWIR (Long Wave Infrared) imaging radiometer integrated to a 6U CubeSat. CIRiS incorporates a versatile on-board radiometric calibration system using views to deep space and to two on-board, flat-panel, carbon nanotube film blackbody sources. CIRiS is able to operate without a cryocooler or scanning mechanism because of its uncooled microbolometer FPA (Focal Plane Array) and pushbroom scanning.

Science: LWIR measurements are important for land and water resource management, research and modeling.

Highlights: The CIRiS spacecraft was launched into Low Earth Orbit on December 5, 2019 and has been undergoing commissioning of the bus and instrument since then. The team will talk about how CIRiS's reduced size, weight and power draw facilitate constellation missions for broader coverage and shorter revisit times.

CubeSat operation comes with the challenge of high sensitivity to on-orbit thermal environment changes because the small instrument envelope limits the use of thermal insulation and damping. Uncooled operation may exacerbate this issue due to higher radiant emission from warmer components. CIRiS employs several methods to reduce these sensitivities, including multiple temperature-stabilized zones and drift correction. The effectiveness of these measures has been investigated in TVAC (Thermal Vacuum) testing on the integrated instrument and spacecraft bus. After on-orbit commissioning they will be validated through a procedure that includes periodic calibration and imaging.

Co-Authors: A. Amparan, A. Ghandour, T. Kampe, P. Kerrigan, J. Necas, D. Piqueira, G. Reavis, R. Rohrschneider, M. Veto and R. Warden

SNOOPI: SigNals-Of-Opportunity P-band Investigation // InVEST-17

James Garrison
Purdue University
jgarriso@purdue.edu

Technology: SNOOPI is a new CubeSat mission to investigate the use of P-band signals of opportunity to measure Root-Zone Soil Moisture (RZSM) and Snow Water Equivalent (SWE).

Science: RZSM (the water content in the top meter of soil) and SWE (the amount of water in snow pack) are important variables that play critical roles in hydrology and water management.

Highlights: Existing satellite-based soil moisture data products can only reliably capture the top layer of the soil (approximately 5 cm below the surface). Furthermore, there are no spaceborne SWE measurements to date. Deeper penetration requires longer wavelengths, like P-band (< 500 MHz). However, spaceborne remote sensing using monostatic radar and/or radiometry within P-band has proven to have significant technical challenges (e.g. large antenna size and radio frequency interference (RFI)). Recent advancements through airborne and tower experiments have provided the fundamental proof of concept for Signals of Opportunity (SoOp) remote sensing. However, adapting the SoOp measurement technique to an on-orbit environment presents three top risks, which can only be studied through spaceflight validation. First, reflected signal coherence at satellite altitude and velocity over widely varying surfaces needs to be characterized. Signal coherence is necessary to make precise phase observations, as required for SWE, and to achieve high signal strength in a specular reflection required by RZSM. Second, robustness in the presence of RFI is a key advantage claimed for the SoOp technique. A thorough assessment of its effects on global scale observations is only possible from the vantage point of space while using the same observation geometry as a future Earth science mission. Third, prediction and tracking of the reflected signal from a spaceborne receiver, given uncertainty in the transmitter orbit position, needs to be demonstrated.

Co-Authors: J. L. Garrison(1), M. A. Vega(2), R. Shah(3), J. Piepmeier(2), D. A. Spencer(1), R. Banting(2), J. C. Raymond(2), R. Bindlish(2), B. Nold(1), M. Fritts (2), K. Larsen(3) (1) Purdue University, (2) NASA GSFC, (3) NASA JPL

HARP: Hyper-Angular Rainbow Polarimeter // InVEST-12

J. Vanderlei Martins
University of Maryland, Baltimore County
martins@umbc.edu

Technology: HARP is a technology demonstration to measure aerosol and cloud droplets using multi-spectral polarization measurements.

Science: The HARP payload is a precursor to the HARP-2 polarimeter that will fly on the NASA PACE mission to collect global data on aerosol and cloud particles.

Highlights: The team will discuss HARP's first light, which was obtained on April 15th, 2020 showing data over Europe in a scene containing aerosols, clouds, ocean and land surfaces. This first image verifies the functionality of the HARP payload and demonstrates its polarization measurements in different angles and wavelengths. HARP is preceded by its airborne version, the AirHARP instrument, which has flown in two NASA aircrafts to demonstrate the capabilities of the HARP payload. AirHARP data was used to support the development of data processing and science retrieval algorithms for the HARP CubeSat and HARP-2 instrument. The team will present results from both the HARP and AirHARP instruments.

Co-Authors: Brent McBride, Anin Puthukkudy, Xiaoguang Xu, Henrique Barbosa, Lorraine Remer

NACHOS: Nano-satellite Atmospheric Chemistry Hyperspectral Observation System // InVEST-17

Steven P. Love
Los Alamos National Laboratory
splove@lanl.gov

Technology: NACHOS is a CubeSat-based high-resolution hyperspectral imager for atmospheric trace gas monitoring. The 3U CubeSat operates in the 300-500 nm spectral region, with f/2.5 optics, 1 nm spectral resolution, 350 spectral channels, and 350 across-track spatial pixels. NACHOS also incorporates rapid on-board gas-retrieval hyperspectral processing.

Science: The instrument will target NO_2, SO_2, O_3, CH_2O and other gases with sufficient spectral resolution to reliably separate trace gas signatures from the atmospheric background. It is spectroscopically similar to NASA's Ozone Monitoring Instrument (OMI) but aimed at much higher spatial resolution, narrow field-of-view targeted observations (~130 km swath width and 0.4 km pixel resolution from 500 km altitude). Potential science missions include monitoring fossil fuel burning and low-level passive degassing at volcanoes.

Highlights: Hyperspectral imagers produce imagery in which each pixel contains a full high-resolution spectrum. They offer the ability to image and quantify atmospheric trace gases and ground materials from space with high sensitivity. The team will talk about how they address the key issue of the CubeSat downlink bottleneck by developing streamlined on-board HSI gas retrieval algorithms that run many times faster than traditional methods. With this instrument as a first demonstration, the team seeks to enable a paradigm shift in spaceborne trace gas spectral imaging, from expensive single-platform instruments to agile constellations of relatively inexpensive instruments on small satellites. Such constellations could be tailored to offer much more favorable combinations of spatial resolution and revisit time than can be achieved by any single instrument.

Co-Authors: L.A. Ott, M. E. Dale, C.L. Safi, H.D. Mohr, K.W. Post, K.G. Boyd, J. Theiler, J. A. Wren, B. R. Foy, A. A. Guthrie, N. Dallmann, and M. K. Dubey

PLENARY

Josep Rosello

June 23 // 3:10PM

The European Space Agency's largest arm is its Earth Observation Programme Directorate. The program is one of the leading world players in Earth science and applications. It aims also to provide societal benefits such as more accurate weather and climate predictions and actionable information for monitoring land, ocean, ice, atmosphere and the solid earth.

Josep Rosello, Head of the Technology Coordination & Frequency Management Section at the European Space Agency, will elaborate on the agency's mission and efforts to bolster Earth observations from space. He will talk about new technologies and vital partnerships that help us provide and obtain robust and accurate Earth observations.

STRENGTHENING EARTH OBSERVATIONS

ESTO fosters a diverse set of projects that broadens ways to observe Earth and improves overall data quality. These investigators are creating new machine learning algorithms, instruments and protocols that can help probe questions about coral reefs, land change and weather phenomena, among many others.

23 Jun 2020 // 3:40PM - 5:00PM

ARCSTONE: Calibration of Lunar Spectral Reflectance from Space

Constantine Lukashin
NASA Langley Research Center
constantine.lukashin-1@nasa.gov

Technology: The ARCSTONE instrument is a compact spectrometer on a CubeSat intended for low Earth orbit. It will measure the lunar spectral reflectance with accuracy < 0.5% (k=1), sufficient to establish an SI-traceable absolute lunar calibration standard referenced to the spectral solar irradiance across the 350 to 2300 nm spectral range.

Science: The ARCSTONE mission goal is to establish the Moon as a reliable reference for high-accuracy on-orbit calibration in the visible and near-infrared spectral region. This lunar reference will help enable high-accuracy absolute calibration and inter-calibration of past, current, and future Earth-observing sensors, meteorological imagers, and long-term climate monitoring satellite systems.

Highlights: The ARCSTONE team will present the laboratory characterization results from two prototyped instruments, one operating in the UV-VNIR and the other in the SWIR; development status of a next-generation full-spectral-range instrument; the intended approach to calibration and characterization; and the planned path toward mission implementation. The Moon's surface reflectance is effectively time-invariant; using the Moon as a high-accuracy calibration reference enables broad inter-calibration opportunities even between temporally non-overlapping instruments, and provides an exo-atmospheric absolute radiometric standard. Calibration accuracy, stability, and inter-consistency among different instruments are key to developing reliable composite data records from sensors in low Earth and geostationary orbits.

Co-Authors: T.C. Stone, G. Kopp, T. Jackson, R. Swanson, E. Minda, C. Buleri, A. Halterman, A. Hoskins, T. Christensen, J.S. Benheim, M. Cooney, H. Courrier, W. Davis, M. Kehoe, T. Nguyen, N. Ryan, P. Smith, M. Stebbins, D. Taylor, C. Young

D-SHIELD: Distributed Spacecraft with Heuristic Intelligence to Enable Logistical Decisions // AIST-18

Sreeja Nag
NASA Ames Research Center
sreeja.nag@nasa.gov

Technology: D-SHIELD is a suite of scalable software tools that helps schedule payload operations of a large constellation with multiple payloads per and across spacecraft.

Science: D-SHIELD can increase measurement samples over multiple spatiotemporal vantage points. To validate D-SHIELD, the team will apply it to schedule representative constellations measuring spatiotemporal distributions of soil moisture, which varies on spatial scales of a few meters to many kilometers and time scales of minutes to weeks.

Highlights: Constellation topology, spacecraft and ground network characteristics can be imported from design tools or existing constellations and can serve as elements of an operations design tool. D-SHIELD will include a science simulator to inform the scheduler of the predictive value of observations or operational decisions. Autonomous, real-time re-scheduling based on past observations needs improved data assimilation methods within the simulator. The team will introduce the modules within D-SHIELD and present their preliminary results.

Co-Authors: Alan Aguilar, Amir Azemati, Jeremy Frank, Richard Levinson, Alan Li, Mahta Moghaddam, Vinay Ravindra, Daniel Selva

NeMO-Net - The Neural Multimodal Observation & Training Network for Marine Mapping // AIST-16

Ved Chirayath
NASA Ames Research Center
ved.c@nasa.gov

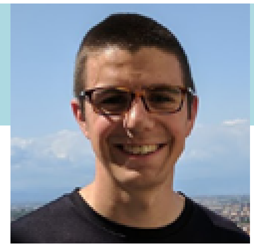
Technology: NeMO-Net is an open-source deep convolutional neural network and interactive learning and training software aimed at assessing the present and past dynamics of coral reef ecosystems through habitat mapping into a number of biological and physical classes.

Science: Shallow marine systems, particularly coral reefs, are under significant pressures due to climate change, ocean acidification, and other anthropogenic pressures, leading to rapid, often devastating changes in these fragile and diverse ecosystems.

Highlights: Historically, remote sensing of shallow marine habitats has been limited to meter-scale imagery due to the optical effects of ocean wave distortion, refraction and optical attenuation. NeMO-Net augments and improves the benthic habitat classification accuracy of low-resolution datasets across large geographic and temporal scales using high-resolution training data from FluidCam. NeMO-Net uses fully convolutional networks based upon ResNet and ReSneNet to perform semantic segmentation of remote sensing imagery of shallow marine systems captured by drones, aircraft and satellites, including WorldView and Sentinel.

Co-Authors: Alan Li, Juan Torres-Perez, Jarrett van den Bergh, Michal Segal-Rozenhaimer

Geostationary Satellites and Deep Learning



Thomas Vandal
NASA Ames/BAERI
thomas.vandal@nasa.gov

Technology: This project uses supervised and unsupervised machine learning techniques to minimize the differences between Earth-observing satellites and to develop new data products.

Science: Recent advances in geostationary (GEO) sensors will soon provide global coverage with a suite of satellites at significantly higher spatial, temporal, and spectral resolutions compared to prior generations. These hardware improvements present opportunities for studying high-frequency events over extended regions from many GEO satellites, currently including GOES-16/17 (NASA/NOAA), Himawari-8 (JAXA), and GEO-KOMPSAT-2A (KMA). Building a consistent low-level data product from this set of satellites would simplify the data analysis process, enable downstream tasks, and more easily allow for cross domain comparisons.

Highlights: GEO satellites have variations in each dimension of resolution, spatial, temporal and spectral, as well as sensor noise. This team presents an optical flow approach for temporal interpolation and atmospheric motion by leveraging high-frequency mesoscale observations and convolutional neural networks. Spectrally, image-to-image translation models with variational autoencoders enable the generation of virtual sensing through synthetic band estimation while learning generalizable representations. This team will discuss how high performance computing is leveraged for development and faster iteration time of experimentation.

PI: Rama Nemani

Simplified Gravitational Reference Sensors for Earth Geodesy Missions // IIP-19

John W. Conklin
University of Florida
jwconklin@ufl.edu

Technology: This team aims to develop a gravitational reference sensor optimized for future Earth geodesy missions that could achieve acceleration noise levels that are at least 100x better than those used on GRACE and GRACE-FO.

Science: Low-low satellite-to-satellite tracking missions that use laser ranging interferometers, like GRACE-FO, are technologically limited by the acceleration noise performance of the electrostatic accelerometers in addition to temporal aliasing issues associated with the dynamic gravity field measurements.

Highlights: Current accelerometers have limited sensitivity. The LISA Pathfinder mission—a technology for the future ESA/NASA LISA gravitational wave mission—recently demonstrated a greater acceleration noise performance. The results of the LISA Pathfinder and extensive ground testing using precision torsion pendula indicate that a simplified version of the LISA Pathfinder gravitational reference sensor, optimized for future Earth geodesy missions, could achieve an acceleration noise at the desired performance level. This sensor could be directly integrated with the laser interferometer, potentially relaxing requirements on spacecraft attitude measurement and control. The improved performance is enabled by increasing the mass of the sensor's test mass, increasing the gap between the test mass and its electrode housing, removing the small grounding wire used in previous electrostatic accelerometers and replacing it with a UV LED-based charge management system, and operating the sensor in a drag-free or a hybrid drift mode control. The instrument would be relatively compact with a mass of ~15 kg and a nominal power consumption of ~20 W per spacecraft.

Co-Authors: Myles Clark, Anthony Y. D'vila Ivarez, William M. Klipstein, Aaron Knudtson, Guido Mueller, Jose Sanjuan Munoz, Robert Spero, Brent Ware, Peter Wass, David Wiese, John Ziemer

Antimonide Barrier Infrared Detector Focal Plane Arrays for Earth Science Applications // SLIT-15

David Z. Ting
Jet Propulsion Laboratory
david.z.ting@jpl.nasa.gov

Technology: A new long-wavelength infrared (LWIR) focal plane array (FPA) has a higher operating temperature, enabling reductions in size, weight and power.

Science: This FPA will enable high-resolution, wide-swath land imaging for future Landsat missions.

Highlights: Antimonide type-II strained-layer superlattices (T2SLS) and alloys have emerged in recent years as viable infrared absorber materials for building high-performance focal plane arrays (FPAs) based on the barrier infrared detector (BIRD) architecture. This team has demonstrated high-uniformity, high-operability antimonide BIRD FPAs with cutoff wavelengths ranging from 2.6 μm in the extended short wavelength infrared (eSWIR) to 13.3 μm in the very long wavelength infrared (VLWIR). This team will discuss NASA Earth Science applications of T2SLS infrared detectors in general and report specifically on results from the development of very long-wavelength infrared (VLWIR) FPAs and an integrated dewar electronics cooler assembly for the ESTO Sustainable Land Imaging-Technology (SLI-T) program.

Co-Authors: Anita Fisher, Sarath D. Gunapala, Cory J. Hill, Sam A. Keo, Arezou Khoshakhlagh, Brian J. Pepper, Sir B. Rafol, Alexander Soibel (Jet Propulsion Laboratory); Steven Allen, Darrel Endres, Robert Jones, Yajun Wei, Diane Beamer (L-3 Cincinnati Electronics)

Mid-Wave and Long-Wave Infrared T2SLS Digital Focal Planes for Earth Remote Sensing Instruments // ACT-17

Sarath Gunapala
Jet Propulsion Laboratory
sarath.d.gunapala@jpl.nasa.gov

Technology: This project aims to achieve advances for two technologies: a Type-II strained-layer superlattice (T2SLS) barrier infrared detector (BIRD); and, a high dynamic range digital read out integrated circuit (DROIC).

Science: These two technologies will enable future missions for Earth Science imaging, spectral imaging, and sounding applications, which have always been among the most challenging in infrared photodetector technology due to the rigorous material growth, device design, and fabrication demands. Small satellites presents even more challenges for long-wavelength infrared (LWIR) focal plane arrays (FPAs), as operating temperature must be increased so that cooler (and radiator) volume, mass, and power can be reduced.

Highlights: T2SLS BIRDs combine the high operability, spatial uniformity, temporal stability, scalability, producibility, and affordability advantages of the quantum well infrared photodetector (QWIP) FPA with the better quantum efficiency and dark current characteristics. A mid-wavelength infrared (MWIR) T2SLS BIRD FPA is a key demonstration technology in the (6U) CubeSat Infrared Atmospheric Sounder (CIRAS) funded under the ESTO InVEST Program. A LWIR T2SLS BIRD FPA is also being developed under the ESTO ACT and SLI-T Program for future thermal infrared (TIR) land imaging needs. DROICs integrate a digital reset counter with a conventional analog ROIC to provide a much higher effective well capacity than previously achievable. The resulting longer integration times are especially beneficial for high flux/dark current LWIR applications as they can improve signal-to-noise ratio and/or increase the operating temperature. By combining the aforementioned technologies, this project seeks to demonstrate a cost-effective, high-performance LWIR FPA technology with significantly higher operating temperature and sensitivity than previously attainable, and with the flexibility to meet a variety of Earth Science TIR measurement needs, particularly the special requirements of small satellite missions.

Co-Authors: Sarath Gunapala, David Ting, Alexander Soibel, Arezou Khoshakhlagh, Sir Rafol, Cory Hill, Anita Fisher, Brian Pepper, Sachidananda Babu, and Parminder Ghuman

EARTHS RADIATION

Earth's radiation drives climate and life on Earth. Although we've been monitoring solar irradiance for over 40 years, there is still much to learn about the Sun's variability. These investigators are developing new instruments to improve and continue this vital dataset.

23 Jun 2020 // 5:10PM - 5:50PM

DEMETER - IIP: DEMonstrating the Emerging Technology for measuring the Earth's Radiation for the Instrument Incubator Program // IIP-19

Anum Barki Ashraf
NASA Langley Research Center
anum.r.barki@nasa.gov

Technology: DEMETER-IIP is an effort to advance an observational capability for monitoring Earth's Radiation Budget from space.

Science: The Earth Radiation Budget Fundamental Climate Data Record (ERB-FCDR) is comprised of global Top-Of-Atmosphere (TOA) broadband radiance fields which include total reflected solar and outgoing longwave radiation.

Highlights: The DEMETER sensorcraft mission solution goes beyond preserving observational and radiometric continuity of the existing multi-decadal FCDR; it exploits new technology, integrating it with existing high TRL capability assets, and capitalizes on concurrent investments in technology demonstration flight programs from multiple agencies. This greatly expands the scientific utility of the Earth Radiation Budget Thematic Climate Data Record (ERB-TCDR). This solution increases the spatial resolution of the measurement by a factor of 10, which enables more accurate clear-versus-cloudy sky investigations and provides in-situ data processing capability on the sensorcraft while also reducing mass, power and cost by an order of magnitude over current approaches. Reduced accommodation requirements enable insertion of the sensorcraft into multiple orbits for more complete global diurnal sampling of the radiation fields, while providing robustness against a possible gap in the observational record.

Co-Authors: Kory Priestley, Mohan Shankar, J.R. Mahan, Alexander Halterman, Talbot Jaegar

BABAR: Black Array of Broadband Absolute Radiometers // IIP-19

Cameron Straatsma
LASP/University of Colorado
cameron.straatsma@lasp.colorado.edu

Technology: A 32-element linear array of room-temperature electrical substitution radiometers fabricated on a thin silicon nitride membrane selectively etched to provide thermal isolation between individual pixels as well as between the pixels and the silicon substrate.

Science: Spectral measurements from space are used in many areas like solar irradiance monitoring, urban land-use and population growth, water quality assessment, fire detection and monitoring, natural disaster damage assessment, soil and vegetation monitoring and weather prediction and monitoring.

Highlights: In this talk, the team will provide an overview of the linear array developed under the BABAR program, as well as a demonstration of closed-loop response to incident optical radiation. Earth's outgoing broadband shortwave and longwave radiation is currently imaged with single-element, scanning thermistor bolometers on the CERES instrument. As a critical quantity in the Earth's radiation budget, it is important to explore alternative broadband radiation imaging technologies that can provide higher spatial resolution and improved radiometric accuracy currently beyond the capabilities of scanning thermistor bolometers.

PI: Michelle Stephens

Co-Authors: Christopher Yung, Nathan Tomlin, David Harber, Odele Coddington, John Lehman, and Michelle Stephens

DAY TWO AT A GLANCE

24 June 2020

12:50PM WELCOME

1:00PM ATMOSPHERE**: Session I**

1:00PM	Thomas F Hanisco – IPDA: Integrated Path Differential Formaldehyde
1:10PM	Scott M. Bailey – GLO: Gas Filter Correlation Radiometer (GFCR) Limb Occultation Sensor
1:20PM	Matthew DeLand – MASTAR: Multi-Angle Stratospheric Aerosol Radiometer
1:30PM	Christopher Ruf – Next Generation Global Navigation Satellite System (GNSS) Bistatic Radar Receiver
1:40PM	Michael J. Kavaya – Wind-SP: Wind Space Pathfinder
1:50PM	Mauricio Sanchez-Barbetty – MASTR: Multi-Application SmallSat Tri-band Radar
2:00PM	Ken Cooper – VIPR: Vapor In-cloud Profiling Radar
2:10PM	Nathaniel Livesey – Continuity MLS: A Continuity Microwave Limb Sounder to extend the 15+ year record from Aura MLS
2:20PM	Q&A

2:40PM BREAK

2:50PM ATMOSPHERE**: Session II**

2:50PM	Roger De Roo – A Novel Microwave Receiver Architecture for Wideband Autocorrelation Radiometry
3:00PM	Jeffrey R. Piepmeier – Correlator and Phased Array Fed Radiometers
3:10PM	William Deal – Integrated Receiver and Switch Technology (IRaST)
3:20PM	Michael A. Kelly – CMIS: Compact Midwave Imaging System
3:30PM	Ashok K. Sood – Development of High-Performance Graphene-HgCdTe Detector Technology for Mid-wave Infrared Applications
3:40PM	Kevin Maschhoff – SToRM SAR: Satellite Tomography of Rain and Motion using Synthetic Aperture Radar
3:50PM	Q&A

4:10PM BREAK

4:20PM ATMOSPHERE**: Session III**

4:20PM	Jeanne Holm – Predicting What We Breathe: Machine Learning, Smart Cities, and Earth Science Data
4:30PM	Derek Posselt – Towards a Scalable Parallel Bayesian Observing System Simulation Framework
4:40PM	John Beck – CAPRi: Cloud-based Analytic Framework for Precipitation Research
4:50PM	E. Natasha Stavros – M2AF: Multi-scale Methane Analytic Framework
5:00PM	Q&A

(All times are in Eastern Daylight Time)

ATMOSPHERE

Session I

It's all around us, but we can't see it unless we use specialized instruments. ESTO helps develop new passive and active monitoring tools to illuminate what's in the atmosphere and support weather forecasters, climate modelers and decision makers, among many stakeholders. These investigators are developing new ways to measure aerosols, monitor clouds and track precipitation. Some focus on building tangible instruments while others are creating virtual tools.

24 Jun 2020 // 1:00PM - 2:40PM

IPDA: Integrated Path Differential Formaldehyde // IIP-19

Thomas F. Hanisco
NASA Goddard Space Flight Center
thomas.hanisco@nasa.gov

Technology: This concept uses a tunable narrow-linewidth fiber amplified solid state laser to remotely detect formaldehyde. The concept relies on a simple Beer's law analysis that is largely independent of the a priori assumptions needed in passive systems, providing improved capability in sensitivity and accuracy.

Science: IPDA aims to improve our understanding of the coupled chemistry-climate system. Formaldehyde is a key measure of the oxidative power of the atmosphere. It is produced in the oxidation of methane and is an important intermediate in the production of ozone.

Highlights: Formaldehyde is an important component of existing (OMI, TROPOMI, OMPS) and planned (TEMPO, GEMS, Sentinel-4) satellite missions. The team will discuss how it intends to demonstrate the capability to detect formaldehyde with a remote target on the ground using commercially available electronics. The team will evaluate and optimize the technique and eventually provide its recommendation for the best path toward an instrument design.

Co-Authors: Demetrios Poulios, Steven A. Bailey, Paul Stysley, Aaron Yevick, Reem Hannun, Andrew Swanson, Julie Nicely, and Glenn Wolfe

GLO: Gas Filter Correlation Radiometer (GFCR) Limb Occultation Sensor // IIP-16

Scott M. Bailey
Virginia Tech
baileys@vt.edu

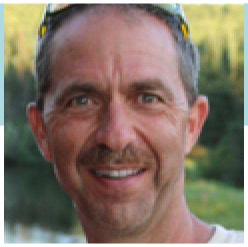
Technology: The GLO (GFCR Limb Occultation) instrument is a VNIR- MWIR space-based solar occultation sensor to measure atmospheric species at less than 1 km vertical resolution. These species are measured through a combination of GFCR channel pairs and single wavelength channels. GLO's small form factor and modest spacecraft accommodation requirements make it well-suited for constellation applications.

Science: The instrument has been designed to particularly target transport and composition of ozone, water vapor, methane, carbon monoxide, hydrogen fluoride, N2O, HCN, HCL, HDO, carbon dioxide (for temperature) and aerosol profiles in the Upper Troposphere Lower Stratosphere (UTLS), but is suited to make observations throughout the middle atmosphere.

Highlights: GLO is a miniaturized, updated version of HALOE (2D focal plane arrays instead of single detectors per channel as used by HALOE), with improved vertical resolution and the addition of three spectrally pure, broadband channels (0.45. 1.020, and 1.556 microns) for stratospheric aerosol extinction. The team will describe an implementation on a mission concept called Composition of the UTLS Experiment (CUE). CUE will quantify the role of the UTLS in climate change by characterizing UTLS transport pathways. The team is almost finished building a balloon-borne version of GLO. Assuming near-normal work policies return in time, the instrument will undergo ground-based testing during Summer 2020 and a first balloon opportunity will occur in September. The instrument concept, measurement approach, retrieval uncertainties, and potential applications as well as any test data available will be discussed.

Co-Authors: S. Bailey (Virginia Tech), R. Bevilacqua, D. Korwan, F. Santiago, J. Bobak, S. Restaino (Naval Research Laboratory), C. Randall (University of Colorado and Laboratory for Atmospheric and Space Physics), L. Gordley, B. Marshall, M. Hervig (GATS, INC)

MASTAR: Multi-Angle Stratospheric Aerosol Radiometer // IIP-16



Matthew DeLand
Science Systems and Applications, Inc. (SSAI)
matthew.deland@ssaihq.com

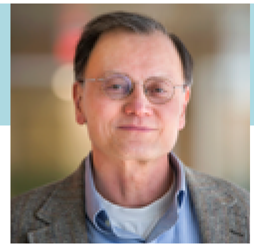
Technology: MASTAR aims to provide simultaneous observations at multiple viewing angles and wavelengths with high vertical resolution and spatial sampling to enhance observations of stratospheric aerosols. MASTAR's observational capabilities sample the full range of scattering angles throughout each orbit to improve sensitivity to aerosols and increase ground sampling compared to current operational systems such as the Suomi NPP Ozone Mapping and Profiling Suite (OMPS) Limb Profiler.

Science: Stratospheric aerosols influence the solar heating of Earth's atmosphere, impacting the extent of climate change effects caused by greenhouse gases. Satellite observations of these aerosols can provide the spatial sampling and vertical resolution necessary to reduce uncertainty in the modeling of radiative forcing, provide correlative measurements for other scientific missions, and monitor dynamic natural events such as volcanic plumes, which have widespread and rapidly changing effects.

Highlights: The team will talk about how the MASTAR design is compact and robust to enable deployment on small satellites. The MASTAR instrument system was first developed as a laboratory proof of concept and has now evolved to a test flight on a high altitude balloon in Summer 2020 to improve technology readiness for future spaceflight operations. The team will describe this process and its long-term plans.

Co-Authors: Matthew Kowalewski (USRA/GESTAR) Peter Colarco (NASA/GSFC) Luis Ramos-Izquierdo (NASA/GSFC) William Mamakos (Design Interface)

Next Generation Global Navigation Satellite System (GNSS) Bistatic Radar Receiver // IIP-16



Christopher Ruf
University of Michigan
cruf@umich.edu

Technology: The Next Generation GNSS bistatic radar receiver is capable of processing signals transmitted by both GPS and Galileo satellites, including both low (L1/E1) and high (L5/E5) bandwidth signals. The receiver is also capable of processing between 7 (minimum) and 14 (goal) simultaneous signals.

Science: This radar receiver will enable major improvements in climate studies, weather monitoring and prediction, soil moisture and flood inundation mapping, disaster management, and uses by commercial maritime organizations.

Highlights: GNSS bistatic radars use the existing constellations of navigation satellites (GPS, Galileo, etc.) as the transmit half of a bistatic radar link. The receive half of the link is a customized GNSS receiver designed specifically for remote sensing applications. As a consequence of these hardware and firmware developments, horizontal resolution is improved by a factor of three, vertical resolution by a factor of ten, and spatial coverage and revisit time by a factor of two (minimum) to four (goal).

Co-Authors: Roger Backhus, Tim Butler, Chi-Chih Chen, Scott Gleason, Ryan Miller, Andrew O'Brien, Line van Nieuwstadt

Wind-SP: Wind Space Pathfinder

Michael J. Kavaya
NASA Langley Research Center
michael.j.kavaya@nasa.gov

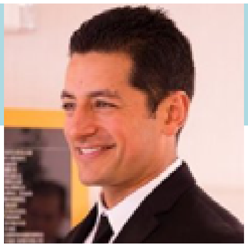
Technology: Wind-SP is advancing the 2-micron pulsed coherent wind lidar technology beyond the proven airborne instrument stage towards space applications.

Science: Wind-SP supports a 3D global wind space mission. Ocean surface wind measurements are critical to understanding and predicting hurricanes, storms and climate change. Wind is the largest source of momentum for the ocean surface, impacting individual surface waves and complete current systems. Wind-SP's energy per pulse and 30 m pulse length will allow us to detect detailed energy flux relevant structures within the marine atmospheric boundary layer (MABL). We will also be able to generate global statistics on MABL depths and energetics.

Highlights: The team will present its project status and future plans. Wind-SP builds on the DAWN airborne coherent wind lidar heritage. In addition to emphasizing compactness, ruggedness and a path to space, several new subsystems were developed for the first time due to the requirements of two alternating lines of sight having very large and opposite sign Doppler shift and maintenance of precise alignment to maximize instrument sensitivity.

Co-Authors: Yu, J. Marketon, L. Petway, J. Lee, T. Wong, S. Henderson. P. Kratovil, D. Bruns, and D. Emmitt

MASTR: Multi-Application SmallSat Tri-band Radar // IIP-16



Mauricio Sanchez-Barbetty
Jet Propulsion Laboratory
barbetty@jpl.nasa.gov

Technology: MASTR is a SmallSat instrument concept capable of electronic scanning, Doppler velocity measurement and polarimetry at Ku/Ka/W-band frequencies. MASTR can work as a cloud and precipitation radar, an altimeter (targeting sea ice height and snow depth) or as a scatterometer (in a spinning configuration). MASTR aims to enable significantly smaller instruments that meet several science needs using a modularized architecture that is flexible and can adapt to multiple measurement objectives.

Science: MASTR supports research into clouds and radiation, precipitation measurements, cryospheric sciences, climate variability and change and physical oceanography.

Highlights: AirMASTR, the airborne demonstration of the MASTR technology, is a scaled version of the MASTR concept designed to fit in the nadir port of NASA's DC-8 aircraft. A modular design allows MASTR to grow in size without significant redesigns. The team will present the status of the hardware development in preparation for engineering flights for AirMASTR.

Co-Authors: Simone Tanelli, Gregory Sadowy, Jet Propulsion Laboratory, California Institute of Technology David Miller, Gary Ayers, Tonda Macleod, Nuvotronics

VIPR: Vapor In-cloud Profiling Radar // IIP-16

Ken Cooper
Jet Propulsion Laboratory
ken.b.cooper@jpl.nasa.gov

Technology: VIPR is a tunable 167-174.8 GHz radar designed to remotely sense humidity and clouds.

Science: VIPR aims to improve the global coverage and spatial resolution of humidity measurements to improve weather forecasting and climate modeling.

Highlights: The team will talk about how coincident humidity measurements using balloon-borne radiosondes validated VIPR's airborne humidity retrievals. Their measurements establish a proof-of-concept for this new differential radar application and provide critical data for defining requirements for a potential future space-based version of VIPR. VIPR can measure humidity inside of clouds with typical accuracies of < 1 g/m^3. In ground testing, VIPR observed ice clouds above 10 km in height. VIPR has also been installed in a Twin Otter aircraft and operated for over 20 hours in an airborne measurement campaign targeting various weather conditions and terrain, as well as water surfaces.

PI: Matt Lebsock **Co-Authors:** Richard Roy, Robert Dengler, Raquel Rodriguez Monje, Maria Alonso-delPino, Jose Siles, Okan Yurdusevan, Chaitali Parashare, Luis Millan, and Matthew Lebsock

Continuity MLS: A Continuity Microwave Limb Sounder to extend the 15+ year record from Aura MLS // IIP-19

Nathaniel Livesey
Jet Propulsion Laboratory
nathaniel.j.livesey@jpl.nasa.gov

Technology: Continuity MLS obtains nearly all of the measurements made by the MLS instrument on Aura (launched in 2004), but in a far more compact form factor (20kg, 40W vs. 500kg, 500W).

Science: Stratospheric ozone layer stability, climate variability and change, and the impact of stratospheric ozone on air quality. Continuity MLS is ideally suited for the Earth Explorer "Ozone and Trace Gas" opportunity and/or to a suitably scoped "Earth Venture-Continuity" opportunity.

Highlights: The team will talk about the potential impact of Continuity MLS. Spaceborne observations have provided important insights into the behavior of Earth's atmosphere. Atmospheric limb sounding (viewing the atmosphere edge-on) offers good vertical resolution; the long atmospheric path viewed provides a strong signal to noise for measurements of tenuous trace gases. For more information, please visit https://mls.jpl.nasa.gov/.

Co-Authors: Nathaniel Livesey, Goutam Chattopadhyay, Adrian Tang, Robert Stachnik, Robert Jarnot, Luis Millan, Michelle Santee, and others from the MLS team, Jet Propulsion Laboratory, California Institute of Technology, Mau-Chung (Frank) Chang, and Rulin Huang, University of California, Los Angeles

ATMOSPHERE

Session II

It's all around us, but we can't see it unless we use specialized instruments. ESTO helps develop new passive and active monitoring tools to illuminate what's in the atmosphere and support weather forecasters, climate modelers and decision makers, among many stakeholders. These investigators are developing new ways to measure aerosols, monitor clouds and track precipitation. Some focus on building tangible instruments while others are creating virtual tools online.

24 Jun 2020 // 2:50PM - 4:10PM

WiBAR: Wideband Autocorrelation Radiometry // IIP-16

Roger De Roo
University of Michigan – Ann Arbor
deroo@umich.edu

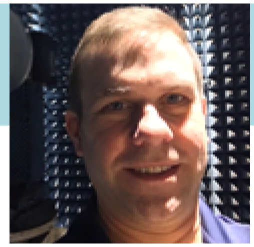
Technology: WiBAR is a novel microwave receiver architecture.

Science: This instrument will measure the thickness of low-loss dielectric slabs, like snow on the ground, and lake ice. WiBAR aims to enable the global quantification of the amount of water in the snow pack reservoir.

Highlights: WiBAR has two thrusts: the first is measurement of snow packs to validate the expectation of a signal. This measurement involves a ground-based L-band radiometer front-end with a spectrum analyzer serving as the back-end. This method is inherently slow, because the spectrum analyzer is viewing only a small portion of the wideband spectrum at a time. The second thrust is a benchtop demonstration of a novel architecture for the receiver, which will decrease the observation time significantly. It employs novel analog and digital components for microwave radiometry. A tunable front-end comb filter, based on an optical Fabry-Perot interferometer, provides adaptive radio-frequency interference (RFI) mitigation. The back-end uses a pair of comparators clocked with slightly different clock rates near 100 MHz, producing sample pairs for autocorrelation that have a 0.2 ns resolution. Progress on these two thrusts will be reported.

Co-Authors: Maryam Salim, Puneeth Yogananda, Steven Rogacki, and Line van Nieuwstadt

Correlator and Phased Array Fed Radiometers // ACT-17



Jeffrey R. Piepmeier
NASA Goddard Space Flight Center
jeff.piepmeier@nasa.gov

Technology: Two multi-band line-array feeds at 10-40 GHz (with polynomial tapered elements) and 10-90 GHz (with uniform taper) were developed to improve the spatial resolution of multi-band passive microwave imagery. The feed at 10-40 GHz was developed for testing in a reflector configuration to demonstrate the ability to generate multiple overlapping beams in elevation; and, the feed at 10-90 GHz was developed to push frequency coverage higher and wider, demonstrating the capability of spanning a wide frequency range of interest for Earth observing radiometers.

Science: Multi-band passive microwave imaging has been used for nearly 40 years to measure precipitation rate, integrated water vapor, integrated cloud liquid water and ice, ocean surface wind speed, snow water equivalent, sea ice concentration and land surface temperature. As geophysical models have improved, the need has emerged to improve spatial resolution to < 5 km.

Highlights: The engineering of antenna systems is a careful balance of frequencies, beam quality, spatial resolution and sampling. Wideband, multibeam array feed technology has the potential to simplify this trade space and avoid trading spatial resolution for sampling. Several critical components were designed in the project including wideband/banded radiating elements, wideband reactive combiners, and frequency separating filters. The project culminated in an array-fed demonstration antenna tested for radiometer beam-forming capability on the GSFC antenna range.

Co-Authors: T. Holmes, J. Jordan, W. Stacy, G. De Amici, A. Mahnad, P. Racette, J. Peng, and R. Rincon

IRaST: Integrated Receiver and Switch Technology // ACT-17

William Deal
Northrop Grumman
william.deal@ngc.com

Technology: This project is addressing two distinct technical challenges: build an integrated receiver designed to measure the 424 GHz oxygen line and 448 GHz water vapor line using a single front-end; and develop integrated circuit switching techniques to reduce 1/f noise in submillimeter wave direct detection receivers.

Science: IRaST is expected to have significant benefits for atmospheric science. The integrated receiver for temperature and water vapor profiling of the upper atmosphere will provide detailed information between 6 to 16 km in the tropical atmosphere. The integrated switch technology will improve cloud ice measurements.

Highlights: The 424/448 GHz receiver will measure both the oxygen line and the water vapor line using a single aperture. The receiver could potentially be used for measuring contrails cumulus clouds. Recent IIP projects (TWICE and SWIRP) have demonstrated low-power direct detection receivers at frequencies as high as 680 GHz. 1/f noise from low noise amplifiers for the direct detection receiver contribute to the receiver NEDT. On TWICE, a simple technique was used to reduce 1/f noise by ~20 dB. IRaST is developing several new techniques for additional 1/f noise improvements. The team will present progress on this task and a new IIP project titled Smart Ice Cloud Sensing (SMICES).

Co-Authors: Xavier Bosch-Lluis, Caitlyn Cooke, Jonathan Jiang, Pekka Kangaslahti, Kevin Leong, and Gerry Mei

CMIS: Compact Midwave Imaging System // IIP-16

Michael A. Kelly
Johns Hopkins University Applied Physics Lab
michael.kelly@jhuapl.edu

Technology: CMIS uses a high-operating temperature (HOT) focal plane array, which requires less cooling and less power than traditional systems. The low resource requirement allow for accommodation on smaller spacecrafts like CubeSats, which potentially enable a multi-satellite constellation.

Science: CMIS was designed to meet science objectives for high spatial- and temporal-resolution observations of the planetary boundary layer (PBL). CMIS provides radiometrically calibrated multi-spectral, multi-angle wide-field-of-view (WFOV) observations in the shortwave-midwave infrared (SWIR/MWIR) of clouds, aerosols and other particulates.

Highlights: The Johns Hopkins University Applied Physics Laboratory (JHU/APL) planned airborne tests of the Compact Midwave Imaging System (CMIS) on the NASA Langley Research Center (LaRC) Gulfstream III for March 2020. However, those plans are currently on hold until normal operations resume at JHU/APL and LaRC. The goal of the airborne test campaign will be to demonstrate the capability of the instrument to retrieve atmospheric motion vectors and cloud-top heights in the PBL. The team will discuss the ground calibration of the instrument and describe plans for the upcoming airborne test campaign.

Co-Authors: Arnold Goldberg, Dong Wu, John Boldt, Ivan Papusha, James L. Carr, and Carol Anne Clayson

Graphene-based Detector Array Technologies

Ashok K. Sood
Magnolia Optical Technologies Inc.
aksood@magnoliaoptical.com

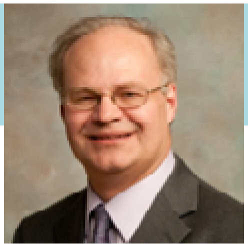
Technology: High performance detector technology is being developed for sensing over the mid-wave infrared (MWIR) band for science, defense and commercial applications. The graphene-based mercury cadmium telluride (HgCdTe) detector technology involves the integration of graphene with HgCdTe photodetectors to combine the best of both materials and allow for higher MWIR (2-5 μm) detection performance compared with photodetectors using only lead selenide (PbSe) material.

Science: The MWIR spectral band of 2 to 5 μm is suitable for a variety of NASA Earth science applications and can be used for measuring sea surface temperature, cloud properties, volcanic activity and fires.

Highlights: Current MWIR detectors require cryogenic cooling to minimize thermally generated signal noise. This cooling requirement substantially adds to the size, weight, power and cost of instruments. This project aims to develop new MWIR detector technology through modeling, material development and device optimization that eliminates the need for cooling. If successful, this technology would enable MWIR sensing applications on smaller satellite platforms like CubeSats, opening doors for new Earth observation measurement capabilities.

Co-Authors: Ashok K. Sood and John W. Zeller Magnolia Optical Technologies, 52-B Cummings Park, Suite 314, Woburn, MA 01801 Parminder Ghuman and Sachidananda Babu NASA Earth Science Technology Office, Greenbelt, MD 20771 Nibir K. Dhar U.S. Army Night Vision & Electronic Sensors Directorate, Fort Belvoir, VA 22060 Samiran Ganguly and Avik Ghosh Department of Electrical & Computer Engineering, University of Virginia, Charlottesville, VA 22904

STORM SAR: Satellite Tomography of Rain and Motion using Synthetic Aperture Radar // IIP-19



Kevin Maschhoff
BAE Systems
kevin.maschhoff@baesystems.com

Technology: SToRM SAR is a space-based 3D multi-static precipitation radar that employs agile micro-satellites operating synchronously in formation to provide 1 km horizontal spatial resolution observations of a precipitation field using a new interferometric method.

Science: Observations at this horizontal resolution are needed to resolve the fine thermodynamic phase structure present in many severe storms, and support the weather process research needed for future convection-resolving weather models. The 5 kilometer horizontal resolution of the large GPM radar is too coarse to resolve these phenomena.

Highlights: The team will explain how SToRM SAR leverages rapid developments in small satellite technology and launch capability to provide a significant new capability at a mission cost more than 10x lower than other space-borne precipitation radars. SToRM SAR aims to penetrate and characterize severe mid-latitude storms at the 1-km scale from space for the first time. Observation locations are cued by passive IR and microwave mapping micro-satellites orbiting ahead, which indicate areas of imminent or ongoing severe weather. This method does not rely on the Doppler Effect for observing storm structure, but uses it to sense field motions- analogous ground-based Doppler-weather radars.

Co-Authors: K. R. Maschhoff, M. F. Ryba, and V. Chandrasakar

ATMOSPHERE

Session III

It's all around us, but we can't see it unless we use specialized instruments. ESTO helps develop new passive and active monitoring tools to illuminate what's in the atmosphere and support weather forecasters, climate modelers and decision makers, among many stakeholders. These investigators are developing new ways to measure aerosols, monitor clouds and track precipitation. Some focus on building tangible instruments while others are creating virtual tools online.

24 Jun 2020 // 4:20PM - 5:10PM

Predicting What We Breathe: Machine Learning, Smart Cities and Earth Science Data // AIST-18

Jeanne Holm
City of Los Angeles
jeanne.holm@lacity.org

Technology: This project looks at the time-series measurements of aerosol and ozone data from public and private ground data sensors, as well as satellite data from MODIS and Terra, and applies machine learning to uncover patterns that may not be discernible to human analysts.

Science: By enhancing our understanding and ability to predict air quality, local governments and others can help mitigate the effects of air pollution through effective interventions.

Highlights: The team will discuss how the City of Los Angeles is in a unique situation to be an urban proving ground to explore ways to better understand, predict and mitigate the issues of air pollution for four million citizens and to share with other cities around the world. Partners on this project include the South Coast Air Quality Management District (AQMD) and the County of Los Angeles, as well as private organizations like Anthem Blue Cross and community groups like the Southern California Asthma Association.

Co-Authors: Mohammad Pourhomayoun, Cal State LA, Christa Hasenkoff, Open AQ, Dawn Comer, Aaron Gross, and Irene Burga, City of Los Angeles

A Scalable Parallel Bayesian Observing System Simulation Framework // AIST-18

Derek Posselt
Jet Propulsion Laboratory
derek.posselt@jpl.nasa.gov

Technology: This framework allows efficient, thorough and quantitative exploration of the trade space of possible instrument configurations with full assessment of the science fidelity.

Science: The target application is a quantitative evaluation of science return from candidate measurements made in the Decadal Survey Aerosols, Clouds, Convection, and Precipitation (A-CCP) mission.

Highlights: Observing System Simulation Experiments (OSSEs) are used to design mission and instrument constellations and evaluate the science return. The trade space that consists of all possible instrument and spacecraft configurations has expanded tremendously with the recent miniaturization of instruments and the rise of SmallSat (and CubeSat) technology. The team will discuss how many instrument configurations are simulated in parallel (the Map step), including measurements (e.g., from spaceborne radar) and retrievals (e.g., ice water path and precipitation content profile). Metrics are then aggregated to compare possible configurations (the Reduce step). In this presentation, the team will describe the system it's developing and will show progress made in the first six months of the project. The team will show results from its first MAP-REDUCE experiments, demonstrate the extensibility of the system to other architectures and highlight how the parallel OSSE concept may be expanded to include broader mission formulation activities.

Co-Authors: Brian Wilson, Rachel Storer, George Duffy, Noppasin Niamsuwan, Benyang Tang, Berlin Chen, and Simone Tanelli

CAPRi: Cloud-based Analytic Framework for Precipitation Research // AIST-18

John Beck
The University of Alabama in Huntsville
john.beck@uah.edu

Technology: CAPRi will leverage cloud-native technologies developed in a previous AIST project titled, Visualization for Integrated Satellite, Airborne and Ground-based data Exploration (VISAGE) to develop an architecture for building Machine/Deep Learning models for precipitation research.

Science: CAPRi aims to enhance the resolution of the Global Precipitation Measurement (GPM) data for improved identification of convective scale precipitation features, particularly outside the coverage of ground-based weather radar. As a science use test case, the team will develop a 3-dimensional precipitation features demonstration database to support the precipitation science community using the new datasets.

Highlights: The team will discuss how CAPRi will host the GPM Validation Network (GPM VN) integrated with a Deep Learning framework to provide an analysis-optimized cloud data store with access via on-demand cloud-based serverless tools. Capri services will automatically generate large volumes of high-quality training data required for the successful development of Deep Learning models. This information systems research will use extended Convolutional Neural Networks (CNNs) to learn features that can infer high-resolution information from low-resolution variables, building on a prototype from previous collaborations with GPM mission scientists.

Co-Authors: Patrick Gatlin, Todd Berendes, Geoffrey Stano, and Anita LeRoy

M2AF: Multi-scale Methane Analytic Framework // AIST-18

E. Natasha Stavros
Jet Propulsion Laboratory
natasha.stavros@jpl.nasa.gov

Technology: M2AF aims to integrate methane data analysis capabilities spanning multiple observing systems and spatial scales into an analytic center framework to increase accessibility and functionality for research community and public and private sector decision makers.

Science: This project will create analytic tools that provide greater insight into methane in the environment.

Highlights: M2AF will be a cross-scale, multi-sensor methane observation data and information system bridging methane research and applied science. This framework lays the foundation for extending existing methane analysis systems beyond their current experimental states, reducing latency and cost of methane data analysis and improving accessibility by researchers and decision makers. To meet these needs, M2AF advances and uniquely brings together multiple observational data sets, models, and analysis methods to estimate methane fluxes across three key, overlapping spatial scales in order to disentangle confounding processes at : 1) global to regional scale, 2) regional to local scale, and 3) facility (point source) scale. M2AF integrates optimized workflows at each scale into a single analytic framework that leverages the NASA Methane Source Finder (MSF) graphical user interface (GUI) and the NASA Science Data Analytics Platform (SDAP) technology for fast, on-demand analytics of cross-scale methane flux estimates. Developing the integrated framework began in February 2020 and is in the initial stages of development.

PI: Riley Duren **Co-Authors:** Andrew Thorpe1, Dan Cusworth1, Brian Bue1, Joe Jacob1, Rob Tapella1, Kevin Gill1, John Worden1, Daniel Jacob4, Vineet Yadav1, 1Jet Propulsion Laboratory, California Institute of Technology 2University of California, Los Angeles 3University of Arizona 4Harvarddonn

DAY THREE AT A GLANCE

25 June 2020

12:50PM WELCOME

1:00PM CHANGES ON LAND: Session I

1:00PM	Marco Lavalle – DARTS: Distributed Aperture Radar Tomographic Sensors
1:10PM	Mahta Moghaddam – SPCTOR: Sensing Policy Controller and Optimizer
1:20PM	Patrick Rennich – Analyzing new data from CIRES: CubeSat Imaging Radar for Earth Science
1:30PM	Philip A. Ely – MURI: Multi-Band Uncooled Radiometer Imager
1:40PM	Andrea Donnellan – QUAKES-A: Quantifying Uncertainty and Kinematics of Earthquake Systems
1:50PM	Q&A

2:10PM BREAK

2:20PM CHANGES ON LAND: Session II

2:20PM	Barton Allen Forman – Exploring the Next Generation of Land Surface Remote Sensing: A Comparative Analysis of Passive Optical, Passive Microwave, Active Microwave, and LiDAR Retrievals
2:30PM	Ethan Gutmann – Building a Snow Model Capable of High Spatial Resolution Simulations into Land Information Systems
2:40PM	Janice Coen – Creation of a Wildland Fire Analysis: Products to enable Earth Science
2:50PM	Q&A

3:10PM SPECTRAL: LAND

3:10PM	Thomas Kampe – CHPS: Compact Hyperspectral Prism Spectrometer
3:20PM	Jeff Puschell – ATLIS: Advanced Technology Land Imaging Spectroradiometer Prototype Testing
3:30PM	Dennis Nicks – REMI: Reduced Envelope Multispectral Imager for Sustainable Land Imaging
3:40PM	Stephanie Sandor-Leahy – Integrated Photonic Spectrometer for Hyperspectral Imaging
3:50PM	K. Jon Ranson – MiniSpec: Miniaturized Imaging Spectrometer to Measure Vegetation Structure and Function
4:00PM	E. Natasha Stavros – GeoSPEC: Geospatial Spectroscopy Processing Environment on the Cloud
4:10PM	Q&A

4:30PM BREAK

4:40PM SPECTRAL: ATMOSPHERE

4:40PM	William H. Swartz – CHAPS-D: Compact Hyperspectral Air Pollution Sensor – Demonstrator
4:50PM	Adam Milstein – CRISP: Computational Reconfigurable Imaging Spectrometer
5:00PM	Tomasz Tkaczyk – TuLIPSS: Tunable Light-guide Image Processing Snapshot Spectrometer
5:10PM	Q&A

5:30PM CONCLUSION Pamela S. Millar // Director, NASA ESTO

(All times are in Eastern Daylight Time)

CHANGES ON LAND

Session I

Ice growing and retreating. Groundwater reservoirs replenishing and diminishing. Wildfires raging and subsiding. Seismic ruptures and aftershocks. These investigators will share new technologies to improve our ability to predict and monitor these phenomena on land and understand their impact.

25 Jun 2020 // 1:00PM - 2:10PM

DARTS: Distributed Aperture Radar Tomographic Sensors // IIP-19

Marco Lavalle
Jet Propulsion Laboratory
marco.lavalle@jpl.nasa.gov

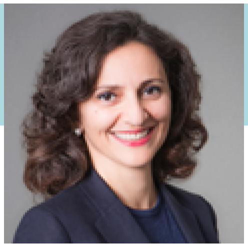
Technology: DARTS matures the technology and performance of a distributed, multistatic radar system for fine-scale imaging.

Science: DARTS aims to enhance global mapping of surface topography and three-dimensional vegetation structure. The system aims to demonstrably retrieve vegetation structural characteristics, including the underlying ground topography, with the desired vertical and horizontal resolutions, accuracy and temporal sampling.

Highlights: The team will provide an overview of DARTS including the science motivation, technology challenges and proposed solutions. It will share initial results obtained with the DARTS performance tool and field experiments. DARTS is designed as an integrated system of systems using and advancing state-of-the-art technologies. The effort focuses on the critical subset of technologies required to implement a multi-static SAR system for spaceborne as well as airborne observations of 3D vegetation structure. The team will discuss fundamental challenges facing the implementation of a coherent distributed system like DARTS such as, 1) an absolute timing reference which is invariant to positioning of the sensor elements, 2) relative positioning and attitude knowledge in three dimensions for all sensor elements, 3) intercommunication and assimilation of each sensor's data for coherent data processing, and 4) miniaturized, lightweight radar components conducive to affordable launch of multi-satellite formation.

Co-Authors: Brian P. Hawkins, Ilgin Seker, Samuel Prager, Robert Beauchamp, Mark Haynes, Razi Ahmed, Matthew Anderson, Soon-Jo Chung, Kai Matsuka, Paolo Focardi, Nacer Chahat

SPCTOR: Sensing Policy Controller and Optimizer // AIST-18



Mahta Moghaddam
University of Southern California
mahta@usc.edu

Technology: New Wireless Sensor Network (WSN) technologies to (a) Develop a Sensing-Policy Controller (SPC) for multi-Agent WSN and Unmanned Aerial Vehicle (UAV) observation strategy coordination and optimization, and (b) Demonstrate real-world integrated operations between in-situ soil moisture WSNs and UAV-based software defined radars (SDRadars).

Science: Soil moisture plays a vital role in the water and energy cycle and drives climate and weather patterns. Current (e.g., SMAP and SMOS) and future (e.g., NISAR) missions have different spatial (100 m x 10s km) and temporal (daily to weekly) mapping requirements, resulting in complex and potentially conflicting demands on in-situ networks for validating their products.

Highlights: The team will discuss its approach to develop hardware that enables communication and data transfer between static SoilSCAPE in situ soil moisture WSNs and mobile UAV-based sensors. Additionally, it will introduce a new physics-aware optimization and decision-making framework, which enables coordination of UAV- and WSN soil moisture sampling strategies. These technology concepts are particularly relevant because existing ground networks have limited capabilities in terms of spatiotemporal sampling flexibility, multi-user coordination, and multi-sensor integration. These limitations are further compounded when multiple users, each with different application requirements, seek access to sensing networks that may have limited resources.

Co-Authors: Dara Entekhabi, Ruzbeh Akbar, Agnelo Silva, and Sam Prager

Analyzing new data from CIRES: CubeSat Imaging Radar for Earth Science // IIP-16

Patrick Rennich
Aloft Research Corporation
patrick.rennich@aloftresearch.com

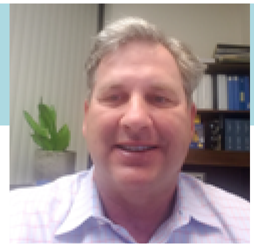
Technology: CIRES is a low-SWaP and low-cost interferometric synthetic aperture radar (InSAR) sensor capable of sub-cm deformation measurements. The CIRES instrument was developed at SRI International and is suitable for deployment on small satellites and other resource-constrained platforms.

Science: Ground deformation measurements obtained from a proliferated set of affordable InSAR sensors, with greater temporal sampling, have the potential to improve short-term forecasting of natural hazards and enable more effective management of natural resources.

Highlights: In December 2019, the CIRES instrument performed an airborne demonstration over a controlled flooding site and produced valuable scientific data. The experiment included a set of radar targets designed to validate its sub-cm level of performance. Aloft Research Corporation has applied calibration and alignment techniques to repeat-track passes from the 2019 CIRES dataset to demonstrate the InSAR measurement capabilities of this type of compact instrument. The team will describe the results, which demonstrate mm-level ground deformation accuracies. The degree of precision achieved by CIRES, plus the increased sampling frequency enabled by a constellation of such low-cost sensors, underscores the potential for compact and affordable InSAR instruments to improve scientific understanding of natural hazards, enhance responsiveness to natural disaster zones, and enable more effective management of natural resources.

PI: Lauren Wye **Co-Author:** David Watters, Aloft Research Corporation

MURI: Multi-Band Uncooled Radiometer Imager // IIP-16



Philip A. Ely
Leonardo DRS
philip.ely@drs.com

Technology: A modern, low cost, large area micro-bolometer FPA imaging radiometer that can be used to provide narrow band, radiometrically accurate imaging in 6 LWIR bands from airborne and space-borne platforms.

Science: This technology aims to help improve how we monitor land surface climatology, soil moisture content, ecosystem dynamics, volcano monitoring, methane detection, hazard monitoring, and geology.

Highlights: The team designed, built, and performed laboratory and airborne flight testing to demonstrate this uncooled micro-bolometer breadboard sensor. MURI PI Philip Ely will share results and imagery, such as radiometric accuracy, NETD and RER, captured during MURI flight tests in California during the Summer of 2019. He will also discuss a third planned flight test for the Summer of 2020 using more sensitive bolometer arrays.

Co-Authors: Ray Wagoner, Leonardo DRS - Col Aaron Gerace, Rochester Institute of Technology

QUAKES-A: Quantifying Uncertainty and Kinematics of Earthquake Systems // AIST-18

Andrea Donnellan
Jet Propulsion Laboratory
andrea@jpl.caltech.edu

Technology: QUAKES-A is an analytic center framework for creating a uniform crustal deformation reference model for the active plate margin of California by fusing InSAR, topographic, and GNSS geodetic imaging data.

Science: QUAKES-A aims to improve understanding of the physical processes leading to and following earthquakes. Users will be able to access and generate custom crustal deformation products for further analysis.

Highlights: The team will discuss its approach to 1) infuse GNSS network solutions into UAVSAR baseline estimation and extract features from InSAR images, 2) develop cluster analysis to identify crustal blocks and rank active fault systems spatially and temporally, 3) interpolate the analyzed InSAR and GNSS data to provide an adaptively sampled deformation field, and 4) assimilate and correlate the crustal deformation products into geodetic/seismicity-based earthquake forecasts and test against past data. All tools and products are open source and available through GeoGateway geospatial web map services (http://geo-gateway.org).

Co-Authors: Michael Heflin, JPL Marlon Pierce, Indiana University Margaret Glasscoe, JPL Brian Hawkins, JPL Lisa Grant Ludwig, UC Irvine Robert Granat, City College of New York Jay Parker, JPL John Rundle, UC Davis

CHANGES ON LAND

Session II

Ice growing and retreating. Groundwater reservoirs replenishing and diminishing. Wildfires raging and subsiding. Seismic ruptures and aftershocks. These investigators will share new technologies to improve our ability to predict and monitor these phenomena on land and understand their impact.

25 Jun 2020 // 2:20PM - 3:10PM

Exploring the Next Generation of Land Surface Remote Sensing: A Comparative Analysis of Passive Optical, Passive Microwave, Active Microwave and LiDAR Retrievals // AIST-18

Barton Allen Forman
University of Maryland
baforman@umd.edu

Technology: An observing system simulation experiment (OSSE) will be used to evaluate different freshwater observing strategies with a particular focus on coupled snow-soil moisture-vegetation at the land surface.

Science: This mission planning tool will help inform experimental design with relevance to global snow, soil moisture and vegetation in the terrestrial environment. An advanced land surface model within the NASA Land Information System (LIS) will be used to model the hydrologic cycle and to quantify the spatiotemporal dynamics of the coupled snow-soil moisture-vegetation system. The end result of this project will be a framework to better decide how best to harness the information content of Earth science mission data in order to better characterize the spatiotemporal dynamics of water in the natural environment.

Highlights: The team will talk about combining the NASA LIS with the Trade-space Analysis Tool for Constellations (TAT-C) to provide a realistic view of land surface conditions as seen by a given space-borne sensor. This view will help define synthetic space-borne retrievals of snow, soil moisture, and/or vegetation for a given configuration of a hypothetical sensor with relevance to the terrestrial environment. The merger of LIS with TAT-C will enable a series of observing system simulation experiments (OSSEs) in order to explore the trade-off in scientific utility of space-borne sensors employing passive microwave radiometers, microwave RADAR, optical radiometers, and LiDAR.

Co-Authors: Sujay V. Kumar, Paul Grogan, Lizhao Wang, Yonghwan Kwon, Rhae Sung Kim, and Yeosang Yoon

Building a Snow Model Capable of High Spatial Resolution Simulations into Land Information Systems // AIST-18

Ethan Gutmann
NCAR
gutmann@ucar.edu

Technology: This project is embedding the spatially explicit SnowModel into NASA-Land Information Systems (LIS) to greatly enhance mission planning and enable a dramatically richer data assimilation system.

Science: This new capability will help produce the best available global snow product. It will make use of a constellation of satellites to better model near surface winds, simulate snow redistribution, and enable more realistic mission planning Observing System Simulation Experiments (OSSEs.)

Highlights: The team will discuss how it's improving the parallel scaling characteristics of core algorithms to make continental or global scale simulations on a 100 m grid feasible. Mission planning and model-data fusion activities need modeling tools available that represent critical processes. Maximizing the information that can be extracted from future snow missions, in particular, and planning for those missions requires the capability of simulating critical processes that are missing from the LIS now. In particular, the spatial heterogeneity of snow on length scales the order of 100 m is a dominant feature of seasonal snow packs, and this heterogeneity is created primarily by a combination of blowing snow redistribution and preferential deposition due to near in surface turbulence. This effect is not currently represented in LIS, and doing so requires fundamental additions to enable inter-process communication, new physical representation, and parallel scaling to enable highly parallel simulations.

Co-Authors: Carrie Vuyovich, Glen Liston, Jessica Lundquist, Barton Forman, Kristi Arsenault, Adele Reinking, Andrew Newman

Creation of a Wildland Fire Analysis: Products to enable Earth Science // AIST-18

Janice Coen
NCAR
janicec@ucar.edu

Technology: Methodology to create, test and assess the first wildland fire analysis (sometimes called "reanalysis") products - standardized, gridded outputs of desired wildfire products produced at regular intervals.

Science: Wildland fire science and related applications have benefited from a wide range of space-based and airborne fire observations, each with different spatial resolutions and revisit frequencies, as additional sensors and constellations continue to be added. The team will produce reanalysis products for a sample of different types of wildfire events including 2-D gridded variables including cumulative burned area extent, active burning areas, and heat release rate for subsequent use by team members who develop additional products, e.g. biomass burning emissions inventories, for the research community and decision makers.

Highlights: The team will discuss how its effort is analogous to atmospheric analyses. These products will integrate dissimilar, disconnected, asynchronous observations using the physical consistency of a model and data assimilation system to fill gaps in time and space, estimate variables that are not directly observed, and create a physically balanced, more complete image of reality and how it changed over time. The team will develop the fire reanalysis methodology using fire detection products and investigate assimilation of supplementary infrared observations. The CAWFE coupled numerical weather prediction - wildland fire model, which has been successfully used to model many wildfire events, will assimilate this remotely-sensed fire detection data to simulate fires' evolution while minimizing variance from those observations.

Co-Authors: Nancy French, Michael Billmire, Charlotte Weinstein, Reid Sawtell, Louis Giglio, and Wilfrid Schroeder

SPECTRAL: LAND

Everything on Earth emits a spectra. Lush green forests appear green during the summer and then yellow and red in the fall. Air pollutants each emit a different spectra, like a footprint. These investigators will talk about creating new ways to observe these footprints to help scientists and decision makers better understand our natural, and sometimes not so natural, world.

25 Jun 2020 // 3:30PM - 4:30PM

CHPS: Compact Hyperspectral Prism Spectrometer // SLIT-15

Thomas Kampe
Ball Aerospace
tkampe@ball.com

Technology: CHPS is a candidate imaging spectrometer technology for future Sustainable Land Imaging missions. CHPS could provide continuous visible-to-shortwave spectroscopic information at high spectral resolutions. CHPS supports continuation of legacy Landsat data products as well as providing spectral information for a broader range of land science products. CHPS features full aperture full optical path calibration, exhibits extremely low straylight and includes low polarization sensitivity.

Science: The multi-decadal data record from the Landsat series of instruments has provided a unique resource for addressing challenges associated with land cover change, land use, disaster relief, deforestation, regional planning and global change research for over 40 years.

Highlights: As part of this effort, the team built, tested and flew the CHPS-AB instrument, an airborne technology demonstration, to validate its performance and acquire spectroscopic data over a variety of land types that the team is making available to the science community.

Co-Authors: Nathan Leisso, Madeline Cowell, Paul Kaptchen

ATLIS: Advanced Technology Land Imaging Spectroradiometer // SLIT-15

Jeff Puschell
Raytheon Intelligence & Space Systems
jjpuschell@rtx.com

Technology: ATLIS is a small (0.04 m3) multispectral pushbroom imager to provide visible through shortwave (VSWIR) calibrated imagery.

Science: ATLIS will demonstrate that a small imager can provide calibrated imagery to support Sustainable Land Imaging.

Highlights: ATLIS is designed to provide imaging spectroradiometry that meets SLI-T RMA key parameters with an instrument that is much smaller than previous land imaging systems. The team will describe recent results from a prototype ATLIS called ATLIS P. The prototype establishes whether this compact, low mass design approach with wide field of view (WFOV), free form reflective telescope, large format, small detector digital FPA and on-chip processing meets SLI-T RMA VSWIR requirements.

Co-Authors: John Schlaerth, Kyle Heidemann, Kushal Mehta, Joe Choi

REMI: Reduced Envelope Multispectral Imager for Sustainable Land Imaging // SLIT-15

Dennis Nicks
Ball Aerospace
dnicks@ball.com

Technology: REMI aims to meet the current Landsat mission requirements with a much smaller volume and lower cost payload by using a high TRL high performance precision pointing mirror and step-stare imaging pattern to minimize aperture size while maintaining signal to noise.

Science: REMI explores one path to meeting the nation's future land imaging needs.

Highlights: REMI features a narrow instantaneous optical field of view that is scanned in the cross-track direction with a precision pointing mirror. The pointing mirror compensates for platform and ground motion while producing contiguous ground coverage in all spectral bands. The team will present the latest status of REMI's development and airborne flight testing. Planned performance testing of REMI includes data acquisition and analysis of real-world scenes from an aircraft flying at an altitude of ~4,000 m.

Co-Authors: Thomas Kampe, Nathan Leisso, Lyle Ruppert, Madeline Cowell, Paul Kaptchen

Integrated Photonic Spectrometer for Hyperspectral Imaging // SLIT-15

Stephanie Sandor-Leahy
Northrop Grumman
stephanie.sandor-leahy@ngc.com

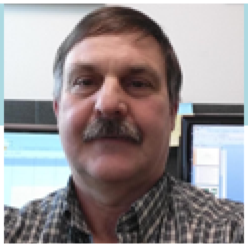
Technology: A hyperspectral imaging spectrometer based on integrated photonics, which offers a novel approach to dramatically reducing instrument size and volume.

Science: This project aims to develop new miniaturized sensors that will enable and advance future Landsat missions.

Highlights: In this approach, lithographically patterned waveguides and planar lightwave circuits integrated with detectors and readout electronics replace discrete free-space optical components and focal plane array assemblies. The technology enables miniaturized sensor packages that acquire data in modes not possible with current imaging instruments. This talk will present progress on hardware developments including photonic waveguide performance and optimization, as well as device integration. The team will summarize its advancements and plans to realize the integrated instrument.

Co-Authors: Richard Davis, Augusto Gutierrez-Aitken, Mark Knight, Lushalan Liao, KK Loi, Wayne Yoshida

MiniSpec: Miniaturized Imaging Spectrometer to Measure Vegetation Structure and Function // IIP-16



K. Jon Ranson
NASA GSFC
kenneth.j.ranson@nasa.gov

Technology: MiniSpec includes two sensors designed to provide diurnal spectral radiance measurements needed for vegetation function and high definition vegetation structure (for inferring scene shadows). MiniSpec will be part of a diurnal SmallSat constellation, which will collect measurements at multiple times per day.

Science: MiniSpec captures vegetation functional response to environmental conditions. Earth's vegetated ecosystems are a key factor for sustaining life on Earth. They provide food, fiber and habitat, enable biodiversity and operate as key components of the carbon, water and energy cycles.

Highlights: The team will discuss how vegetation can be estimated by remote sensing and light use efficiency (LUE) models that take into account vegetation stress from lack of nutrients and soil moisture, as well as harmful levels of temperature and solar radiation. Shadows caused by 3D structure and solar angle, however, limit measurement accuracy from space. Furthermore, current methods and concepts require sensors with multi-angle views to infer shadow fraction. This important diagnostic is lacking in currently flying and proposed systems and requires a constellation of satellites to obtain data at multiple times during a day.

Co-Authors: Philip Dabney, Joe Howard, Ray Ohl, Fred Huemmrich

GeoSPEC: Geospatial Spectroscopy Processing Environment on the Cloud // AIST-18

E. Natasha Stavros
Jet Propulsion Laboratory
natasha.stavros@jpl.nasa.gov

Technology: GeoSPEC prototypes an on-demand science data processing system (SDPS) on the cloud for imaging spectroscopy Level 1 calibrated radiance data through Level 3+ information products.

Science: GeoSPEC allows users to access and develop science data products for imaging spectroscopy data on the cloud. This prototype will help advance the study of Surface Biology and Geology (SBG) globally, a designated observable recommended by the 2017 Earth Science and Applications Decadal Survey. Key SBG science products include foliar functional traits (such as canopy nitrogen) and fractional surface cover, which have demonstrated algorithms at local-to-regional scales. GeoSPEC also aligns with priorities of other NASA Earth Science Programs like Carbon Cycle and Ecosystems, Biodiversity, and the NASA Applied Science Program Ecological Forecasting. It aims to serve user communities of LP DAAC and the ORNL DAAC.

Highlights: The analysis required to transform high-dimensionality at-sensor L1 measurements to L3+ products are substantial and may vary locally. GeoSPEC demonstrates an on-demand science data system, creating a user work environment co-located in the cloud with the data, thereby reducing download volumes and increasing collaboration. The team will talk about how GeoSPEC leverages existing NASA-funded information technologies such as HySDS used by the SWOT and NISAR cloud-based science data systems, the Multi-mission Algorithm and Analysis Platform (MAAP), ECOSIS (a crowd-sourced spectral database), and ECOSML (a crowd-sourced model database). The team will demonstrate GeoSPEC on the Terrestrial Ecosystem use case processing through to foliar traits and fractional cover.

PI: Phil Townsend **Co-Authors:** E. Natasha Stavros, Phil Townsend, George Chang, Hook Hua, Thomas Huang, Justin Merz, Winston Olson-Duvall, Sujen Shah, David R. Thompson

SPECTRAL: ATMOSPHERE

Everything on Earth emits a spectra. Lush green forests appear green during the summer and then yellow and red in the fall. Air pollutants each emit a different spectra, like a footprint. These investigators will talk about creating new ways to observe these footprints to help scientists and decision makers better understand our natural, and sometimes not so natural, world.

25 Jun 2020 // 4:40PM - 5:30PM

CHAPS-D: Compact Hyperspectral Air Pollution Sensor Demonstrator // IIP-19

William H. Swartz
Johns Hopkins Applied Physics Laboratory
bill.swartz@jhuapl.edu

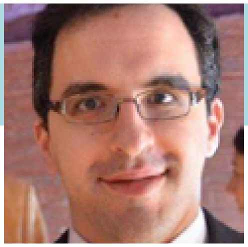
Technology: CHAPS is a hyperspectral imager using freeform optics in a form factor suitable for a small satellite or hosted payload. Its compact size and relatively lower cost makes a constellation feasible for the first time, with unprecedented spatiotemporal sampling of global point pollution sources.

Science: CHAPS-D will make measurements of air pollution at unprecedented spatial resolution from low Earth orbit and will characterize, quantify, and monitor emissions from urban areas, power plants, and other anthropogenic activities. Air pollution is responsible for ~7 million premature deaths every year. Current and planned low Earth orbit and geostationary satellite instruments have long provided global surveys, revealing pollution characteristics and trends. We need a robust, sustainable observing strategy, however, for measuring the distribution of air pollution at high spatial and high temporal resolution.

Highlights: The team will share the measurement requirements and preliminary design of CHAPS-D. The team is working on an airborne demonstration of a CHAPS prototype instrument. CHAPS derives heritage from the TROPOspheric Monitoring Instrument (TROPOMI) on the Sentinel-5 Precursor, which uses a freeform mirror telescope. Freeform optics has potentially huge advantages over traditional optical designs, including fewer optical surfaces, less mass and volume, and improved image quality. CHAPS-D combines a radiometrically calibrated freeform hyperspectral imager (300 by 500 nm at 0.5-nm resolution) with associated detector and payload electronics within the design constraints of a 6U CubeSat.

Co-Authors: Nickolay Krotkov, Lok Lamsal, Frank Morgan, Philip M. Huang, Joseph Linden, Pieternel Levelt, Pepijn Veefkind

CRISP: Computational Reconfigurable Imaging Spectrometer // ACT-17



Adam Milstein
MIT Lincoln Laboratory
milstein@ll.mit.edu

Technology: CRISP is a compact, low power thermal infrared hyperspectral imaging system. CRISP's advantageous use of computational imagery provides increased performance in a smaller and simpler platform compared to traditional solutions.

Science: Spaceborne spectral imagers have provided decades of continuous and highly valuable data that are used for several applications, including surface imaging, atmospheric composition and weather.

Highlights: CRISP's novel design provides three overarching advantages relative to other spectral imaging solutions: (1) a lower SWaP solution with high performance via the use of uncooled components; (2) high spatial resolution, limited only by the optical system and not by the frame rate of the imager; and (3) reconfigurable operation. These advantages are achieved via the use of an encoding mask and optical design that enable multiplexing of spectral information and encoding of fast temporal information.
The future of spaceborne remote sensing will include measurements that are distributed throughout large constellations of smaller spacecraft equipped with more affordable and integrated payloads capable of autonomous mission planning, intelligent data processing and reconfigurable sensing. The team will describe CRISP's recent results and assess its performance. It will also talk about how CRISP's unique design has enabled its rapid evolution from concept to successful flight demonstration.

Co-Authors: Yaron Rachlin, Charles Wynn, Ryan Sullenberger, Corrie Smeaton, Philip Chapnik, Steve Leman

TuLIPSS: Tunable Light-guide Image Processing Snapshot Spectrometer // IIP-16

Tomasz Tkaczyk
Rice University
ttkaczyk@rice.edu

Technology: A fiber-based snapshot imaging spectrometer capable of imaging in VIS and NIR spectral windows.

Science: TuLIPSS will be able to perform a wide variety of Earth remote sensing observations, including recording transient surface and atmospheric phenomena and providing multiple views through an atmospheric column for tomographic studies.

Highlights: The system's principle is based on the application of a custom imaging fiber bundle to re-organize the input vs. output of the fiber structure. The team will focus on system implementation updates, including throughput analysis and improvement of the light collection efficiency. It will also briefly describe the system's operation, discuss re-imaging configurations and present examples of imaging results including those obtained for moving scenes / engineering flight experiments.

Co-Authors: David Alexander, Christopher Flynn, Jiawei Lu, Ye Wang, Razvan I Stoian, Desheng Zheng